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# The Effects of Crowding, Density, and the Duration of Each on Learning

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THE EFFECTS OF CROWDING, DENSITY, AND

THE DURATION OF EACH ON LEARNING

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## ABSTRACT

Ninety-six male albino rats were housed from weaning in groups of 4, 8, or 16 animals. For all group sizes, animals were housed either in cages of a constant size (crowding) or in cages with floor space proportional to group size (density). Six animals from each of these conditions were tested for learning after either 55 or 109 days on a straight alley, a Lashley III maze, and a Y-maze. On the straight alley, no significant differences in running speed were found between durations, crowding and density, or group size. A significant trials effect was obtained ($F=63.28$, $df=15/900$, $p < .01$). On the Lashley III, a significant trials effect was obtained for running speed ($F=102.27$, $df=8/480$, $p < .01$) and errors ($F=63.80$, df-8/480, $p < .01$). The duration comparison showed the 55 day group making significantly more errors than the 109 day group ($F=5.36$, $df=1/60$, $p < .05$). No significant differences were found on running speed or errors between crowding and density or group size. On the Y-maze, the 55 day group had significantly more avoidances than the 109 day group ($F=6.47$, $df=1/60$, $p < .05$). The density groups took significantly fewer trials to reach criterion ($F=4.44$, $df=1.60$, $p < .05$) and a greater percentage of correct responses ($F=4.48$, $df=1/60$, $p < .05$) than the 109 day group.

The results were discussed in terms of methodological inconsistency and the distinction between density and crowding.

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## INTRODUCTION

In recent years the topic of overcrowding has received much attention. This attention has been focused on primarily three areas of research: animal studies (Calhoun, 1962), human studies (Bickman, 1973), and correlational studies (Munroe & Munroe, 1973). The studies of overcrowding have investigated various biological and behavioral reactions to overcrowding. Some of the biological changes found have shown crowded Ss to have a higher adrenal weight (Brian, 1970), higher pituitary weight (Bell, Miller, Ordy, & Rolstein, 1971), reduced reproductive potential (Snyder, 1968), and increased biological stress (Christian, 1955). Other researchers have found behavioral changes, with respect to crowding, such as social ranking (Chapman, Desjarden, & Bronson, 1969; Davis & Christian, 1957), increased aggression (Healy, 1967; Moyer, 1968), territory formation (Mackintosh, 1970), altered activity levels (Bell et al., 1971), and emotionality (Broadhurst, 1958). In spite of the interest and extensive work attributed to the topic of overcrowding, one area, learning ability, has received limited attention. The results of this limited research have been contradictory and inconclusive.

Goeckner, Greenough, and Mead (1973) found deficits in the learning ability of hooded rats reared in crowded environments. They placed rats in groups of 4, 10, 16, 24, and 32 per cage at weaning (24-26 days old). Each group occupied a 36x12x10 in. cage with both males and females in them. Prior to testing all Ss had toys and forms rotated in their cages daily and were given 15 min. of group play in a 4x4x4 ft. object-filled field every three days. On day 51 all Ss were placed on a 23 3/4 hr. water deprivation schedule. Beginning on day 52, eight males from each group were given 15 pretraining trials over an eight day period in a 44 in. straight alley for a .5 cc water reward. From day 60 to day 65 all Ss received one trial on a four-unit eight-cul Lashley III maze (Greenough & McGaugh, 1965) every other day; from day 66-69, the Ss received three trials every other day for a total of 9 trials. After the final maze trial, all Ss were returned to ad-lib food and water. On day 71, all Ss were given one trial in a balanced order on an inhibitory avoidance task. On the "training trial", a door was raised and the Ss allowed to step on a grid floor, where they received a severe foot shock (approximately 3 milli-amperes for .5 sec.) and was removed after about 10 sec. On day 72, the Ss received a test trial which was identical except that the shock was turned off. Latency to step to the floor was recorded. On days 73-75, the Ss were trained in a balanced order to actively avoid shock in the same apparatus. On each trial the S was placed on the grid floor, and the door was raised, allowing him to jump to the platform. If the S did not jump within 5 sec., he received a mild foot shock (approximately

.7 milliamperes) which continued until he escaped by jumping to the platform. Each S was trained to a criterion of 9 out of 10 trials on which he avoided shock (30 sec. ITI). On days 77-80, the Ss were trained in a balanced order to avoid or escape shock by choosing the lighted arm of a symmetrical Y-maze. The S was placed in a lighted arm with the shock off in the last 6.5 in. After 60 sec., the light was switched off in the occupied arm and switched on in one of the other two, following a Gellermann (1933) series, and the shock was switched of in all but the last 6.5 in. of the unoccupied dark alley. If the S did not avoid by moving to the lighted alley within 5 sec., shock was delivered throughout the maze except for the last 6.5 in of the lighted (correct) alley. When the S reached the lighted alley, he was allowed a 60 sec. rest, after which the sequence was repeated until 9 out of 10 correct initial choices had been achieved. The results of this study indicated that performance on complex tasks was affected by population density in the rearing environment, while performance on simpler tasks was realtively unaffected. Total errors and total number of errorless trials on the Lashley III maze differed significantly across groups, with the higher density groups performing poorer than the lower density groups. No significant differences were found on either the inhibitory avoidance task or the active avoidance task (both judged to be simple tasks). The discriminated avoidance, however, produced a significant trials to criterion difference across groups, with the low density groups superior to the high density groups.

Goeckner, Greenough, and Maier (1974) also found deficits in learning ability as a function of high density rearing. In this study rats were weaned at 25-26 days of age and placed in groups of 1, 4, or 32. Isolated Ss occupied a 22.5x30x25 cm. cage and grouped Ss were housed in cages measuring 90x30x25 cm. Behavioral testing began after 50 days of these rearing conditions. Ten animals in each density group were given inescapable electric shock 24 hours before escape training. All Ss were tested for escape/avoidance performance in a Lehigh Valley shuttlebox (21x21x45 cm.). On each trial the S was presented with a 500-Hz tone. After 5 sec., electric shock (1 mA) was delivered. On the first 5 trials a correct response was crossing through the opening to the opposite side of the box, terminating the shock. For the remaining 25 trials, the Ss were required to cross to the opposite side and return to terminate shock. The latency of response was recorded. If the S failed to respond within 30 sec. of shock onset, the trial was terminated and a latency of 35 sec. was recorded. Exposure to inescapable shock produced failure to learn in all populations. The data also showed Ss (not given inescapable shock) in the low densities as having significantly shorter latencies than those in the high density group. This seems to confirm the finding that deficits in learning of complex tasks occur as a function of high density rearing.

A study by Levitt and Bennett (1972) produced contradictory results to those already presented. The researchers employed a modified Grice discrimination apparatus (Gibson & Walk, 1956) to assess the effects of crowding on learning in rats. They set up four groups as follows: (1) crowded/early stimulus experience (CE), (2) crowded/no early stimulus experience (CNE), (3) uncrowded/early stimulus experience (UCE), (4) uncrowded/no early stimulus experience (UCNE). The two crowded groups were housed 10 per cage (5x 9.5x10 in.) while the uncrowded groups were housed 2 per cage (5x9.5 x10 in.), allotting the uncrowded Ss five times the floor space of the crowded Ss. The early experience conditions gave these Ss a preexposure to circles and triangles (the to-be-discriminated forms). All Ss were randomly placed in their respective groups at weaning (21 days old). Cage size was uniformly increased for all groups during the experiment so that each S in the crowded groups had just enough floor space so no animal was lying on top of another. (At the end of the experiment all cages were 10x9.5x10 in.). On day 80, all Ss were placed on a 23-hr. food deprivation schedule. From days 90 to 95, Ss were given five days of discrimination pretraining. At this point the circle-triangle discrimination problem was begun. This continued with 12 trials per day until the S made 18 out of 20 correct responses or a total of 300 trials. As was hypothesized, the preexposure groups learned the discrimination in significantly fewer trials than the non-exposed groups. Contrary to the hypothesis, however, the crowded

Ss learned the task in significantly fewer trials than the uncrowded Ss. When all four groups were compared the following was found: the CE group was significantly superior to all others, the CNE group was next and slightly, though not significantly superior to the UCE group, followed by the UCNE group.

Wood and Greenough (1974) produced identical results to those of Levitt and Bennett (1972), though the former employed a different methodology. These experimenters housed rats individually from weaning till they were 95 days old. They were then randomly rehoused into the experimental conditions. Individually housed rats (GP1) were kept in 22.5x30x25 cm. cages. Socially housed animals were placed in groups of four (GP4) or 16 (GP16) in 90x30x25 cm. cages. Behavioral testing was begun after either one or four weeks of these housing conditions. Each size-duration group contained 16 animals. Three days prior to testing the Ss were placed on a 23-hr. water-deprivation schedule. They were then pretrained in 13 trials over seven days to run a 110 cm. gray straight alley. Upon completion of pretraining, Ss were given three trials per day for three days on a four-unit eight-cul Lashley III maze (Greenough & McGaugh, 1965). Two days after the final maze trial the Ss were trained to escape or avoid footshock by running to the lighted arm of a symmetrical Y-maze (details: Goeckner et al., 1973) according to a Gellerman (1933) series, to a criterion of 9 out of 10 correct initial choices (escape or avoid). Their data analysis showed that grouping (GP4) or crowding (GP16) or previously isolated adult rats facilitated acquisition of complex learning tasks. For the Lashley III maze, one week of differential housing produced a significant overall effect in which both GP4 and GP16 were superior to the isolates. The effects after four weeks were not significant. On the Y-maze task, no significant differences occurred in trials to criterion after one week. After four weeks, however, a significant effect of housing appeared, with GP16 superior to GP4 and GP1.

A study by Taylor (1969) seems to, in part, confirm the Levitt-Bennett and Wood-Greenough studies. Taylor's rats were housed in 11x8x10 3/4 in. cages immediately after weaning (22 days old). They were housed one, seven, or 13 per cage. They were left, undisturbed, in their respective conditions until day 52. On days 53-55, experimental animals from each condition were given one two-minute trial each day in an open field test. On day 56, experimental animals were given three water escape trials on Problem 1. Problem 1 was the Rabinovitch-Resvold (1951) revision of the Hebb-Williams water maze. The authors defined this task as a "relatively simple" problem. Problem 4, "a relatively difficult" problem from the Rabinovitch-Resvold study, was also employed by the Taylor study. Experimental Ss were administered three trials a day on this task on days 57-59. An ITI of at least five minutes was used. When the data were analyzed, a significant inverse relationship was found between density and errors on Problem 1, with the higher densities committing fewer errors. On Problem 4, no systematic relationship was found between density and error scores when these were analyzed over all three days. However, only the error scores for the last day of Problem 4 were considered a significant direct linear relationship was found between errors and density.

To this point, all of the studies presented have utilized animals (specifically, rats) to test the effects of crowding on learning ability. A study by Sherrod (1974), however, used human Ss to investigate this area. This study included three conditions of crowding: (1) noncrowded (2) crowded, (3) crowded-with-perceived control. Three groups of eight Ss each were run in each condition. (One S was disqualified because she did not meet the selection criteria.) All Ss were female high school students paid $5.00 for participation in the two hour experiment. The experimental room which served as the noncrowded condition contained 150 square feet and the crowded condition room contained 37 square feet. The crowded-with-perceived control group was told that they could leave the room (37 sq. ft.) and move to a large classroom setting to complete the experiment if they wished, but that it was preferred that they remain in the 37 sq. ft. room. As a cover story, all Ss were told that the experiment dealt with the effects of acoustical environments on task performance. Each group was directed to their assigned rooms and spent the first hour on a series of tests designed to measure the effects of crowding on simple and complex task performance. Ss were then returned to a reception room where they spent the second hour under "normal noncrowded" conditions working on two additional tasks designed to assess the effects of the original crowding manipulation on postcrowding behaviors. These tasks involved a puzzle solving measure of frustration tolerance and a proofreading measure of quality of performance. For the final phase of the experiment the Ss filled out a one page questionnaire concerning their reactions to the experiment. The results revealed that crowding had no significant effect on any of the six tasks included as measures of simple task performance. Crowding also had no significant effect on the complex tasks (four sets of the Stroop test). Finally, no significant differences in task performance were found between the crowded and the crowded-with-perceived control conditions.

Another study utilizing humans as Ss was done by Freedman, Klevansky, and Ehrlich (1971). In Experiment I of this three part experiment they placed either five or nine Ss in rooms of 35, 80, or 160 square feet. Each Ss sat in a chair with a desk-type arm. The Ss in this study were 84 boys and 42 girls from a nearby high school, that had volunteered and were paid $1.75 per hour for participation in the 10 hour experiment. A total of 18 groups were run. (Twelve had all males, six had all females; half had five Ss and half had nine

Ss per room.) Each group was assigned to one of the rooms for the first session. On the second and third session the group was placed in a different room, so that each group worked in each size room (counterbalanced over the three sessions). A session consisted of seven tasks. Task 1 was a group discussion of a current problem. Task 2 (crossing-out) required the S to cross out all of a certain number from a random table. Task 3 (forming words) required the S to form as many English words from six letters given by the E. Task 4 (divergent thinking or object uses) asked the S to give as many alternate uses for a common object that he could. Task 5 (memory), eight lists of 12 words each were read aloud at a rate of one per second, the S wrote the ones he recalled on paper. Task 6 (concentration) required the S to count the number of clicks he heard (15-57 clicks at a rate of 3 per sec. with varied intervals between clicks). Task 7 was a repeat of Task 4 only the Ss worked as a group. The results were summarized, in short, by saying that there were no effects of any kind attributable to the level of density in the rooms. High density neither facilitated nor interfered with performance on either simple or complex tasks, and there was no indication that density produced greater effects over time, nor were there any noticeable trends. In Experiment II they slightly modified their procedure. This time they used 34 groups of 7 to 9 Ss in each. Only the largest and the smallest rooms and only three tasks were used (crossing-out, forming words, and an anagram task). Each task was repeated a number of times. They manipulated motivation (a monetary bonus for good performance) for half of the Ss. Just as found in the first study, there were no significant effects or trends in the data. Experiment III replicated this study with the exception that 180 women (25-60 years old) were used as Ss instead of high school students. Again, no effects or trends were found.

The studies cited to this point have shows increases and decreases in animal (rats) learning and no effects on human task performance as a function of crowding. This paper has devoted a great deal of effort to presentation of the methodologies employed in the studies of overcrowding. After reviewing these studies, it becomes apparent that there has been wide variation in the methodologies employed. Many potentially confounding factors such as, age at the time of crowding (this has been suggested as a confounding factor by the data obtained by Goeckner et al., 1974 and Wood & Greenough, 1974) and the number of Ss that constitute crowding have varied from study to study. Another important factor which has been confounded by these studies is the difference between spatial crowding and density. The former placing different size groups in a constant size cage and the latter having cage-floor space proportional to group size. One study has directly compared these two conditions (Bell, Miller, Ordy, & Rolstein, 1971).

Bell et al. (1971) housed all crowded mice (CG) regardless of group size, in cages measuring 12 1/2 x 13 x 6 1/2 inches. For the density group (DG) the cage size depended on the number of mice in the group, allotting each mouse 20 1/2 square inches of floor space. All Ss were placed in groups of 1, 4, 8, 16, or 32. All Ss were kept in their respective housing conditions for 75 days. The physiological measures obtained found differences for CG and DG groups. Activity wheel data showed an interactive function of group size by CG-DG housing. The DG group's activity decreased as group size increased 1-16, and then increased with further increases in group size. The CG groups showed decreased activity as group size increased. The direction of the differences between the CG and DG groups on the physiological and behavioral data is not important to this study. The important point is simply that there were differences between the CG and DG conditions.

Another methodological inconsistency that has been suggested as a confounding factor is the duration of crowding. By way of example, Levitt and Bennett (1972) tested their Ss after 90 days of crowding, while Goeckner et al. (1973) tested their Ss after 52 days of crowding. Wood and Greenough (1974) did vary the duration of crowding (using durations of one and four weeks), but the one week condition was an extremely short duration to attempt comparison. Differences were found between the one and four week conditions.

The general purpose of the present study will be to investigate the effects of differential housing on subsequent learning tasks in rats. This general purpose will be accomplished through manipulation of the following four variables: First, this study will attempt to eliminate some of the methodological inconsistencies already mentioned, by replication of the general methodology employed by Goeckner et al. (1973), Goeckner et al. (1974), and Wood and Greenough (1974). Second, this study will investigate the differential effects of density contrasted with crowding. Density will be defined as having the cage-floor space proportional to group size, while crowding will be defined as having different size groups in the same size cage. Third, it is hypothesized that there will be a within group effect in both the density and crowding conditions, as a function of the level (# of Ss) of each. Fourth, the effects of duration on density and crowded housing will be investigated by testing after two different periods of time (52 days and 104 days).

# METHOD

## Subjects

A total of 113 male albino rats were obtained from the Holtzman Breeding Laboratories. Ninety-six of these served as experimental Ss and the remaining 17 served as replacement animals. All Ss weighed approximately 55 grams and were 21 days old when obtained. During the early stages of the study nine animals died from a bacterial pneumonia. Sulfadimethoxine and Polyotic tetracycline hydrochloride administered in the drinking water was found to be effective in arresting this disease before the third week of the experiment. Any dead animal was removed and replaced with a specially marked animal that was not used as a test S, but merely maintained the planned housing conditions.

## Apparatus

Housing:

Experimental cages--Eleven plywood cages with wire mesh floors and tops, measuring 90x30x25 cm.; two cages measuring 90x60x25 cm.; one measuring 120x90x25 cm.

Replacement cages--Four plastic tubs measuring 32x24x18 cm., filled with sawdust, housed the replacement animals.

Testing:

Appetitive tasks--A 110 cm. straight alley was constructed of plywood. A four-unit eight-cul Lashley III alley maze was also used (Greenough & McGaugh, 1965).

Discriminated escape/avoidance task--A symmetrical Y-maze with each arm measuring 41x15x23.75 cm. was used. The walls were black Plexiglas, the cover was of clear Plexiglas and the entire maze had a grid (1/8 inch diameter) floor. Cue lights (24 volts, General Electric 1829) were centered 12.5 cm. above the floor on the end wall of each arm (Goeckner, Greenough, & Mead, 1973).

## Procedure

All Ss were randomly assigned to treatment conditions immediately upon arrival in the laboratory (day 1). Treatment (housing) conditions are presented in Table 1. All Ss remained in their respective conditions, undisturbed except for cage cleaning and replacement procedures already described, until day 52 on a 12 hour diurnal cycle. On day 52, all Ss were placed on a 23 3/4-hour water deprivation schedule. Also on day 52, 12 Ss were randomly selected from each housing condition. Each group of 12 was then randomly divided into two groups of six. Each animal was marked with an animal identification number. One of these groups (Duration 1) began testing three days later (day 55) and the other on day 109 (Duration 2).

TABLE 1

TREATMENT CONDITIONS

| CROWDING* | | | | | |
|---|---|---|---|---|---|
| Number of Cages | Cage Size | Total Cage Space | Number of Ss/cage | Space per Ss | Total Ss |
| 4 | 90x30x25 cm | 2700 $cm^2$ | 4 | 675 $cm^2$ | 16 |
| 2 | 90x30x25 cm | 2700 $cm^2$ | 8 | 337 $cm^2$ | 16 |
| 1 | 90x30x25 cm | 2700 $cm^2$ | 16 | 168 $cm^2$ | 16 |

| DENSITY* | | | | | |
|---|---|---|---|---|---|
| Number of Cages | Cage Size | Total Cage Space | Number of Ss/cage | Space per Ss | Total Ss |
| 4 | 90x30x24 cm | 2700 $cm^2$ | 4 | 675 $cm^2$ | 16 |
| 2 | 90x60x25 cm | 5400 $cm^2$ | 8 | 675 $cm^2$ | 16 |
| 1 | 120x90x25 cm | 10800 $cm^2$ | 16 | 675 $cm^2$ | 16 |

*Both duration groups were housed in the same cages (55 day animals were replaced in cages after testing).

On days 53 and 54, the first group of test Ss were placed in individual stainless steel cages during the day, given 15 minutes access to water, and returned to their home cages at night.

Beginning on day 55, all test Ss received two trials (30 sec. ITI) per day over an eight-day period, in a balanced order, in the straight alley for a .5 ml. water reward. During testing hours (8:00 A.M. - 8:00 P.M.) the Ss were again kept in individual stainless steel cages, and the animals remaining in the home cages were given water. Test Ss received 15 minutes access to water in the individual cages 1 1/2 hours after each daily pair of trials. Beginning on day 59, test Ss were given 30 minutes access to water in order to forestall any further weight losses. Following pretraining, the Ss were randomly divided into two groups. One group was trained in the Lashley III maze on day 63 and alternate days thereafter, and the other group was trained on day 64 and alternate days thereafter. From day 63 through day 68, all Ss received one maze trial every other day; from day 69 through day 72, the Ss received three trials (30 sec. ITI) every other day (a total of nine trials in all). An error was scored each time a rat's head crossed a line 5 cm. past the choice point in a blind alley. After the final trial, all of the animals were returned to ad-lib water and given one day rest (day 73).

On days 74 through 76, the Ss were trained in a balanced order (12 Ss per day) to escape or avoid shock by choosing the lighted arm of the Y-maze. All Ss remained in individual cages on day 74 through day 76. Training occurred in a dimly illuminated room. The S was placed in a lighted arm with the shock off in the last 16.25 cm. of the arm. After 60 seconds, the light was switched off in the occupied arm and switched on in one of the other two, following a Gellermann (1933) series, and the shock (approximately 3 milliamperes delivered from a BRS-Foringer Model SGS001 shock generator) was switched off in all but the last 16.25 cm. of the unoccupied lighted alley. If the S did not avoid by moving to the lighted alley within 5 seconds, shock was delivered throughout the maze except for the last 16.25 cm. of the lighted (correct) alley. When the S reached the lighted alley, he was allowed a 60-second rest, after which the sequence was repeated until 9 out of 10 correct initial choices had been made (escape and avoidance). On some trials the Ss "froze", a prod was given by slapping the top of the maze with a glove. An error was recorded when the S's body, exclusive of the tail, had entered the dark alley. If the S did not reach criterion within 50 trials, he was removed and given the score at which he would have reached criterion had all successive trials been correct.

This entire procedure, from day 52 through day 76, was repeated for the second duration group, beginning water deprivation on day 106 and testing occurring from day 109 through day 130 in the manner described for the first duration group.

# RESULTS

## Straight Alley Maze

Straight alley times were converted to common logarithms (Kirk, 1968). Table 2 presents the analysis of variance summary table for these converted times. There was a significant overall trials effect ($F=63.28$, $df=15/900$, $p < .01$) with running speed negatively accelerated, and a significant trials across duration interaction ($F=3.86$, $df=15/900$, $p < .01$), with duration stable and trials negatively accelerated. No significant differences were found between durations (A), crowding and density (B), or group size (C). (See Table 2 for F values.)

## Lashley III Maze

Table 3 presents the analysis of variance summary table for running speed (converted to logarithms) and errors for the Lashley III maze. One animal's data was dropped because it was traumatized by the door to the goal box dropping in front of it. After this it sat in front of the goal, but refused to enter. His scores were replaced by obtaining the mean value for time and errors on each trial from the remaining five animals in the same treatment condition. A significant overall trials effect was obtained for both running speed ($F=102.27$, $df=8/480$, $p < .01$) and errors ($F=63.80$, $df=8/480$, $p < .01$). Both of

TABLE 2

STRAIGHT ALLEY ANOVA

| Source | df/df | Times in Logarithms F | MS |
|---|---|---|---|
| A | 1/60 | .1025 | .2169 |
| B | 1/60 | .3136 | .6637 |
| C | 2/60 | 1.587 | 3.359 |
| D | 15/900 | 63.28** | 6.743 |
| AB | 1/60 | 1.055 | 2.233 |
| AC | 2/60 | .3375 | .7143 |
| BC | 2/60 | 1.154 | 2.443 |
| AD | 15/900 | 3.863** | .4116 |
| BD | 15/900 | .6986 | .0744 |
| CD | 30/900 | .7920 | .0843 |
| ABC | 2/60 | .1982 | .4196 |
| ABD | 15/900 | .7309 | .0778 |
| ACD | 30/900 | .7727 | 8.233 |
| BCD | 30/900 | 1.072 | .1142 |
| S(ABC) | 60 | | 2.116 |
| ABCD | 30/900 | .5542 | .0590 |
| SD(ABC) | 900 | | .1065 |

*$p < .05$
**$p < .01$

A = Duration
B = Crowding vs. Density
C = Group Size
D = Trials
S = Subjects

TABLE 3

LASHLEY III ANOVA

| Source | df/df | Times in Logarithms F | Times in Logarithms MS | Errors F | Errors MS |
|---|---|---|---|---|---|
| A | 1/60 | 2.381 | .6438 | 5.365* | 165.0 |
| B | 1/60 | .4266 | .1153 | .5533 | 17.01 |
| C | 2/60 | .4300 | .1162 | 1.230 | 37.82 |
| D | 8/480 | 102.2** | 5.022 | 63.80** | 1196.6 |
| AB | 1/60 | .0220 | .0059 | 1.084 | 33.34 |
| AC | 2/60 | .5016 | .1356 | 2.332 | 71.72 |
| BC | 2/60 | .8682 | .2347 | .2347 | .1805 |
| AD | 8/480 | 3.405** | .1672 | 1.403 | 26.32 |
| BD | 8/480 | .9241 | .0453 | 1.037 | 19.45 |
| CD | 16/480 | 1.342 | .0659 | 1.730* | 32.45 |
| ABC | 2/60 | .6328 | .1711 | .7917 | 24.34 |
| ABD | 8/480 | 1.535 | .0753 | 1.651 | 30.97 |
| ACD | 16/480 | 1.168 | .0573 | .9363 | 17.56 |
| BCD | 16/480 | 2.205* | .1082 | .9971 | 18.70 |
| S(ABC) | 60 | | .2703 | | 30.75 |
| ABCD | 16/480 | .4781 | .0234 | .7017 | 13.15 |
| SD(ABC) | 480 | | .0491 | | 18.75 |

*p $<$ .05
**p $<$ .01

A = Duration
B = Crowding vs. Density
C = Group Size
D = Trials
S = Subjects

these curves were negatively accelerated. The duration comparison showed the 55 day group making significantly more errors than the 109 day group ($F=5.36$, $df=1/60$, $p < .05$). A significant trials-duration (AD, with duration stable and trials negatively accelerated) interaction ($F=3.40$, $df=8/480$, $p < .01$) and density-group size-trials (BCD, with trials negatively accelerated and B, C stable and parallel to each other) interaction ($F=2.20$, $df=16/480$, $p < .05$) were also obtained for the running speeds. A significant group size-trials (CD, with group size stable and trials negatively accelerated) interaction ($F=1.73$, $df=16/480$, $p < .05$) was found for the error scores. No significant differences were found on running speed between durations (A), either dependent measure between crowding and density (B), or group size (C).

## Y-Maze

Table 4 presents the analysis of variance summary table for trials-to-criterion, avoidances, ITI errors (defined as the S leaving the non-electrified section during the inter-trial-interval and stepping onto the electrified grid), and the percentage of correct responses on the Y-maze. The 55 day group had significantly more avoidances than the 109 day group ($F=6.47$, $df=1/60$, $p < .05$), but no significant differences were obtained on the other three dependent measures. Also, the density groups took significantly fewer trials to reach criterion than the crowded groups ($F=4.44$, $df=1/60$, $p < .05$) and had a significantly greater percentage of correct responses ($F=4.48$, $df=1/60$,

TABLE 4

Y-MAZE ANOVA

| Source | df/df | Trials to Criterion F | Trials to Criterion MS | Avoidances F | Avoidances MS | ITI Errors F | ITI Errors MS | % of Correct Responses F | % of Correct Responses MS |
|---|---|---|---|---|---|---|---|---|---|
| A | 1/60 | .0006 | .1250 | 6.475* | 9.388 | 1.428 | 147.3 | .0754 | 24.50 |
| B | 1/60 | 4.444* | 889.0 | 2.452 | 3.555 | .0034 | .3472 | 4.489* | 1458.0 |
| C | 2/60 | .2838 | 56.76 | .0670 | .0972 | .8520 | 87.87 | 1.065 | 346.0 |
| AB | 1/60 | .1056 | 21.12 | 2.452 | 3.555 | .8835 | 91.12 | .0828 | 26.88 |
| AC | 2/60 | 1.081 | 216.3 | .1820 | .2638 | .7814 | 80.59 | .2827 | 91.79 |
| BC | 2/60 | .9554 | 191.0 | .4119 | .5972 | .8776 | 90.51 | 2.342 | 760.7 |
| ABC | 2/60 | .5118 | 102.3 | .8716 | 1.263 | 1.045 | 107.7 | .4245 | 137.8 |
| S(ABC) | 60 | | 200.0 | | 1.450 | | 103.1 | | 324.7 |

*$p < .05$
**$p < .01$

A = Duration
B = Crowding vs. Density
C = Group Size
D = Trials
S = Subjects

$p < .05$), but no significant differences on the other dependent measures. No significant differences were found in relation to group size (C).

# DISCUSSION

The present study, though a general replication and extension of the Goeckner et al. (1973, 1974) and Wood and Greenough (1974) studies, failed to confirm most of the results obtained by these researchers. They found a general decrement in learning when crowding began at weaning (Goeckner et al., 1973; 1974) and a general enhancement of learning when crowding began after maturity was reached (Wood & Greenough, 1974). The current study found no significant differences in the learning ability of rats raised from weaning in groups of 4, 8, or 16. This finding was very surprising considering the methodological similarity between the Goeckner studies and the present one. Only two apparent differences in methodology occurred.

First, the Goeckner et al. (1973, 1974) studies allowed their Ss a series of "play" periods while the present study did not. It seems unlikely, however, that this factor was the source of the discrepancy. One would assume that these "play" periods would not produce a decrement, but rather that they would have a facilitative effect or no effect on learning, unless a high order interaction was active between crowding and these "play" periods. However, considering the results of the current study, this possible interaction seems to merit investigation.

The second methodological difference was the strain of Ss employed. Goeckner et al. (1973, 1974) used hooded rats, while this investigation used albino rats. This discrepancy suggests the possibility of "strain specific" reactions to crowding. It may be that the less domesticated hooded rat is more sensitive to crowding. Direct manipulation of this variable also seems necessary before any strong conclusions can be made on the effects of crowding on learning.

The second general purpose of this study was to investigate the different effects of density and crowding, as defined by Bell, Miller, Ordy, and Rolstein (1971) on learning. This variable's effect was seen on the dependent measures of trials to criterion and percentage of correct responses on the Y-maze task, but not on any others. These measures indicated, as expected, that the performance of the density groups was superior to that of animals in the crowded groups. This seems to cast doubt on the findings of studies that have shown crowded Ss performance on learning tasks to be superior to that of non-crowded Ss (Levitt & Bennett, 1972; Taylor, 1969; Wood & Greenough, 1974). All of these studies appear to have confounded crowding with density. It may be that what they observed was the effect of density overcoming the effect of crowding. This is exactly what was observed in the present study. When density was separated from crowding, the density groups showed better learning. Thus the "inter-animal-stimulation" caused by the presence of other animals may be the relevant factor.

The third hypothesis, which predicted different learning ability as a function of group size, was not confirmed. As already noted, the Goeckner et al. (1973, 1974) and Wood and Greenough (1974) studies found differences as a function of group size, where no differences were found in the present study. The methodological differences might be an explanation for this discrepancy, but other studies (Levitt & Bennett, 1972; Taylor, 1969) have used different methodologies and found significant differences as a function of group size. These studies, however, do not agree with the Wood and Greenough (1974) conclusion that rats crowded from weaning will show poorer learning than non-crowded rats. Levitt and Bennett (1972) and Taylor (1969) found the reverse. The present study's failure to find significant differences as a function of group size in either the density or the crowded conditions seems to cast further doubt on the Wood and Greenough (1974) conclusions. It seems from the results of the present study, taken in consideration with the previous ones, that no conclusions can be offered without further control and methodological uniformity. It may be found that the effects of crowding on learning may be very sensitive and even dependent on the methodology employed, not a simple main effect.

Another possible explanation for the failure to find differences in relation to group size might be that the limited space (crowded conditions) or numbers (density conditions) were not sufficiently diverse or of large enough magnitude to produce any differences in performance.

This, however, does not seem likely when the Goeckner et al. (1973, 1974) studies are considered. It may be, however, that albino rats need to be maintained under more severe conditions than hooded rats in order to produce similar effects. This possibility needs to be investigated.

The fourth hypothesis was that density and crowding would be effected by the duration of each. No significant differences appeared for either one (represented in Tables 2, 3, and 4 as AB). An overall difference was observed between durations with the animals tested after 109 days making fewer errors on the Lashley III than the 55 day group, regardless of whether they were in density (B2) or crowding (B1) conditions. Conversely, the 55 day group made significantly more avoidances than the 109 day group on the Y-maze. These findings are in disagreement with the results of most studies that have directly investigated age differences (Munn, 1950). These studies have, in general, shown that there are no differences in learning as a function of age after the animal has reached 30 day of age. The results of the present study contradict this conclusion. This indicates the need for more research in the area of age differences, but discussion of this issue is beyond the purposes of this paper. The major point that needs to be made is that animals that are housed in crowded or dense conditions for 55 days days do not do significantly better on learning tasks than those under identical conditions for 109 days.

The results of the present study, then, have added two questions which need further investigation. First, exact replications of the "crowding" studies are necessary before conclusions can be offered, due to the discrepancy between the Goeckner et al. (1973, 1974) studies and the present one. These methodological inconsistencies have occurred between most of the studies that have been done on crowding. Uniformity must be obtained before comparisons may be made between these studies. Second, and probably most important, that a distinction needs to be made between crowding and density. Density being defined as having many interacting individuals and crowding, each animal having less space. Therefore, by design, the crowding conditions have a greater density also, because most studies increase the number of animals per cage to achieve crowding. One method of separating these two factors was shown in the present study. Another method would be to maintain group size constant and decrease the space, rather than the standard method of increasing group size. These possibilities need to be investigated.

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